



MICROFAUNA OF MIOCENE DEPOSITS IN THE SOUTH CASPIAN BASIN: STRATIGRAPHIC AND PALEOECOLOGICAL IMPLICATIONS

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ABSTRACT

The Miocene succession of the South Caspian Basin represents an important interval for regional stratigraphic correlation and reconstruction of the basin's geological history. This study presents the results of a comprehensive investigation of microfaunal assemblages recovered from offshore wells located in the Azerbaijani, Turkmen, and Kazakh sectors of the Caspian Sea. The analysed material contains a diverse assemblage of foraminifera and ostracods, including 95 species of foraminifera assigned to 39 genera and 40 species of ostracods belonging to 12 genera. The composition and distribution of these microfossils provide valuable information on the stratigraphy and paleoenvironmental evolution of the basin during the Miocene. Characteristic assemblages were identified within the Tarkhanian, Chokrakian, Karaganian, Konkian, Sarmatian, and Meotian deposits, allowing reliable differentiation and correlation of these stratigraphic units across numerous offshore structures. Variations in species diversity, abundance, and taxonomic composition reflect significant environmental changes throughout the Miocene. The microfauna record indicates fluctuations in salinity, water depth, and basin connectivity, documenting alternating phases of restricted and more open marine conditions. Ostracods demonstrate particularly high stratigraphic significance and serve as effective indicators for distinguishing Miocene horizons. The observed faunal changes reflect the combined influence of regional tectonic activity, sedimentary processes, and variations in connections between the Paratethys and neighbouring marine basins. These factors controlled the development of depositional environments and influenced the distribution of microfauna communities. The obtained results refine the Miocene stratigraphic framework of the South Caspian Basin and emphasise the importance of micropaleontological data for stratigraphic interpretation, paleoenvironmental reconstruction, and hydrocarbon exploration.

Keywords: South Caspian Basin; Miocene; ostracods; foraminifera; micropaleontology; Paratethys; stratigraphy; paleoecology.

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1. Introduction

Hydrocarbon productivity in Azerbaijani and Turkmen sectors of the offshore South Caspian Basin is primarily associated with the deposits of the Productive Series (Pliocene), which are composed mainly of sandstones, sandy siltstones, and alternating sand-clay layers. However, studies have shown that, in addition to the Pliocene reservoirs, Miocene deposits in several Azerbaijani fields also contain considerable oil and gas reserves [1, 2].

Commercial accumulations of oil and gas onshore in Turkmenistan, Kazakhstan, and Azerbaijan have been discovered not only in Pliocene deposits, but also in older stratigraphic units. The objective of this study is to investigate Miocene deposits in the offshore part of the Caspian Sea based on data obtained from wells that penetrated these sediments (figs. 1-3).

Miocene deposits of the South Caspian Basin play a crucial role in the regional Oligocene–Miocene petroleum

system, which extends across the entire basin. To date, approximately 620 oil and gas fields have been discovered within stratigraphic intervals ranging from the Miocene to the Quaternary. Consequently, the investigation of Miocene sediments has both scientific and practical importance, particularly for hydrocarbon exploration, stratigraphic correlation, and basin analysis [2-5].

In terms of hydrocarbon potential, Miocene sediments represent one of the most important sedimentary complexes of the South Caspian Basin after the world-famous Productive Series. In several areas of Azerbaijan, hydrocarbons are produced from Miocene strata. For example, in the onshore Gobustan region, oil and gas production is associated with the Maykop and Chokrak formations, while the Karaganian and Konkian regional stages are also considered promising targets for hydrocarbon exploration [6].

The study of Miocene stratigraphy based on both microfaunal and macrofaunal assemblages is therefore an important and timely task. Detailed analysis of fossil assemblages provides valuable information for the subdivision and correlation of stratigraphic horizons and improves our under-

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standing of depositional environments within the basin.

Micropaleontological analysis is widely applied in the petroleum industry to determine the age of sediments, reconstruct depositional environments, and establish correlations between wells. In particular, microfossils such as foraminifera and ostracods are valuable stratigraphic indicators due to their rapid evolutionary rates and sensitivity to environmental changes.

The present study focuses on the microfauna of Miocene sediments encountered in offshore exploration wells drilled in the marine part of the South Caspian Basin. Most of the data presented in this paper have not previously been published because offshore drilling results in the Caspian Sea were historically restricted from public release. The material analysed in this study was collected during marine drilling

campaigns conducted between the mid-1980s and mid-1990s, providing a unique dataset for understanding the stratigraphy and paleoenvironmental evolution of the Miocene deposits in the Caspian Sea.

2. Materials and methods

Studied Wells and Sampling. The study is based on core materials from 134 exploration and engineering wells drilled in 35 offshore structures located in three sectors of the Caspian Sea (table 1).

Core samples were collected from Miocene intervals penetrated during offshore drilling campaigns. The supplementary file includes tables 2-4 listing the wells, structures, and coring intervals in which Miocene deposits were studied.

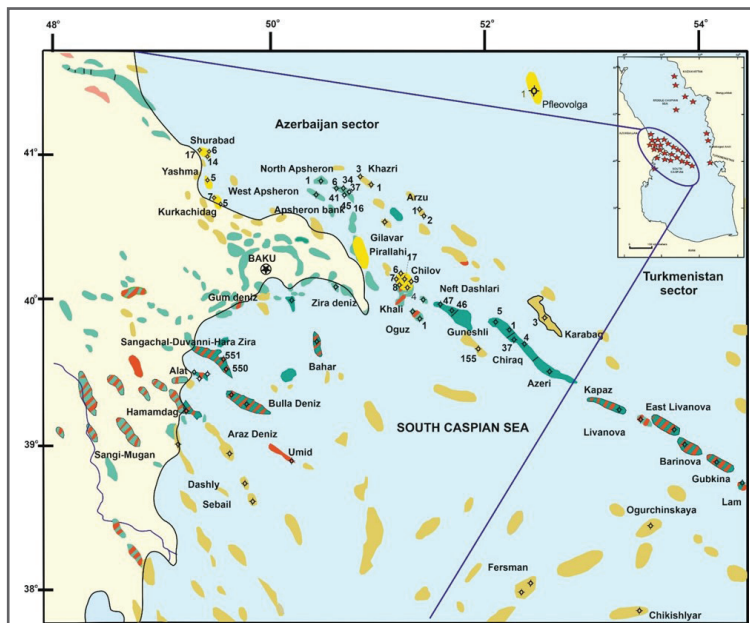


Fig. 1. Map showing the location of wells that penetrated Miocene deposits in the offshore Azerbaijani sector of the Caspian Sea

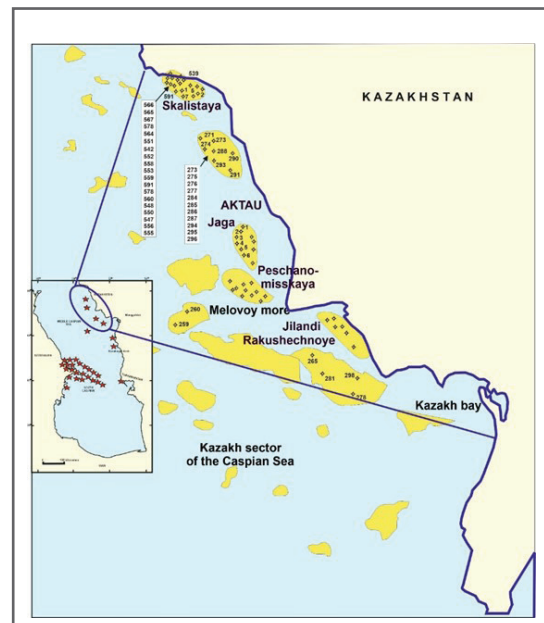


Fig. 3. Map illustrating the locations of wells that penetrated Miocene deposits in the offshore Kazakh sector of the sea

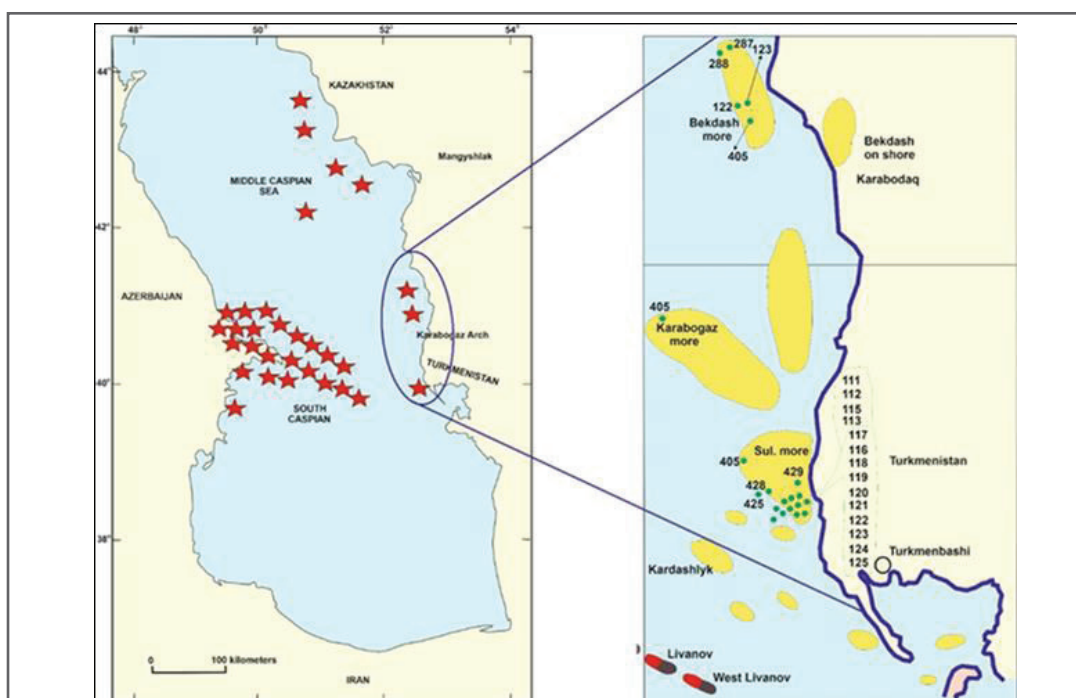


Fig. 2. Map showing the location of wells that penetrated Miocene deposits in the offshore Turkmen sector of the Caspian Sea

Micropaleontological examination of the samples was carried out in the laboratory using standard preparation and analytical procedures.

At the initial stage, the samples were visually inspected using a hand lens with magnifications of 10–20× to evaluate lithology and the potential presence of microfossils. The samples were then disaggregated using either a 5–10 % sodium carbonate solution (Na_2CO_3) or a 10% hydrogen peroxide solution (H_2O_2), depending on the lithological composition of the rock. Clay-rich or relatively indurated samples that did not disintegrate during normal soaking were gently heated in refractory cups using an electric furnace to facilitate disaggregation. After treatment, the samples were washed through a 63 μm sieve to remove fine silt and clay particles.

The remaining residue was subsequently dried in a laboratory drying cabinet. The dried material was then separated into grain-size fractions, and microfossil remains were manually

Table 1 List of studied structures, wells and samples from the South Caspian basin			
Sector	quantity of structures	quantity of wells	quantity of samples
Azerbaijan	29	48	375
Turkmenistan	2	31	119
Kazakhstan	4	55	324
Total	35	134	818

Table 2 List of studied structures, wells, and sampling intervals from the Turkmen sector of the South Caspian Sea						
Turkmenian sector of Caspian sea						
Structure	Well №	Interval in m.	Thickness in m	Age	Interval of sampling	Number of samples
Bekdash more	122	10-130	120	Sarmatian	10-20; 100-110; 120-130	3
	123	0-100	100		0-10; 50-60; 90-100	3
	288	0-80	80		0-10; 40-50; 70-80	4
Sue more	101	0-65	65		0-10; 50-60; 60-65	3
	102	0-45	45		0-10; 30-40; 40-45	3
	103-	0-90	90		0-10; 20-30; 80-90	3
	107	0-101	101		0-10; 20-30; 50-60; 90-101	4
	111	0-110	110		0-10; 15-25; 45-55; 100-110	4
	112	0-120	120		0-10; 40-50; 70-80; 110-120	4
	113	0-110	110		0-10; 60-70; 100-110	3
	115	0-125	125		0-10; 50-60; 90-100; 115-125	4
	116	0-125	125		0-10; 30-40; 70-80; 120-125	4
	117	0-115	115		0-10; 40-50; 70-80; 110-115	4
	118	0-125	125		0-10; 50-60; 90-100; 115-125	4
	119	0-125	125		0-10; 40-50; 70-80; 115-125	4
	120	0-101	101		0-10; 20-30; 50-60; 90-101	4
	121	0-130	130		0-10; 30-40; 70-80; 120-125; 125-130	5
	122	0-120	120		0-10; 30-40; 70-80; 110-120	4
	123	0-120	120		0-10; 30-40; 70-80; 110-120	4
	124	0-118	118		0-10; 40-50; 70-80; 110-118	4
	125	0-80	80		0-10; 30-40; 70-80;	3
	127	0-100	100		0-10; 40-50; 70-80; 90-100	4
	303	0-110	110		0-10; 30-40; 70-80; 100-110	4
	304	0-135	135		0-10; 30-40; 70-80; 110-120; 130-135	5
	305	12-75	63		12-20; 30-40; 70-75	3
	426	10-130	120		10-20; 30-40; 70-80; 110-120; 120-130	5
	427	16-81	65		16-20; 40-50; 71-81	3
	428	5-50	45		5-10; 40-50	2
	429	6-61	55		6010; 50-55; 55-61	3
Sue more	427	106-116	10	Chokrakian	106-110; 110-116	2
	428	95-125	30		95-100; 120-125	2
	429	86-106	20		86-96; 96-106	2
Bekdash more	287	0-110	110		0-10; 30-40; 70-80; 100-110	4
Bekdash more	405	90-110	10	upper Maycopian suite	90-1100; 100-110	2

extracted under a binocular microscope using a fine brush or needle. This procedure allowed the careful isolation of microfauna components from the sediment matrix.

Following the preparation and isolation stages, the taxonomic composition of the microfauna was examined and identified in the laboratory using a Nikon biological microscope under appropriate magnification. The identification of microfossils was based on morphological characteristics of the specimens and comparison with published taxonomic descriptions.

3. Geological setting and stratigraphy

The South Caspian Basin formed as part of the Paratethys realm, which during the Oligocene and early Miocene extended from western Turkmenistan to the Black Sea region. During this time, marine conditions allowed deposition of the organic-rich Maykop Suite, which later became the principal hydrocarbon source rock of the basin [3].

Tectonic uplift of the Greater Caucasus and Kopet Dag mountain systems gradually restricted the basin's connection

Table 3

List of studied structures, wells, and sampling intervals from the Azerbaijani sector of the South Caspian Sea

Azerbaijan sector of Caspian sea						
Structure	Well №	Interval in m.	Thickness in m	Age	Interval of sampling	Number of samples
İsland Chilov	6	112.5-340	227.5	Pontian	112.5-113; 330-340	2
	8	802-846	44		802-805; 840-846	2
	65	1601-1604	3		1601-1604	1
	4	682-805	123		682-685; 800-805	2
Apsheron bank	45	918-923	5		918-923	1
	16	780-900	120		780-790; 890-900	2
	37	611-620	9		611-620	1
Guneshli	5	3722-3730	8		3722-3730	1
	1	3905-4230	325		3905-3910; 4220-4230	2
Chirag	4	3993-3995	2		3993-3995	1
Kapaz	1	4950-5000	50		4950-4955; 4990-5000	2
Arzu	2	2860-2950	90		2860-2870; 29445-2950	2
Khazri	1	2705-3078	373		2705-2710; 2070-3078	2
Oguz	1	4415-4604	189		4415-4420; 4550-4560; 4600-4604	3
Karabag	3	3703-3840	137		3703-3707; 3830-3840	2
Kurkachidag more	7	569-625	56		569-580; 580-591; 591-595; 595-605; 605-615; 615-625	6
Shurabad more	6	210-461	251		210-220; 300-310; 455-461	3
Neft Dashlari	46	1100-1102	2		1100-1102	1
Shurabad more	6	473-545	72	Meotian	473-480; 480-490; 490-500; 500-510; 510-520; 520-530; 530-540; 540-543	8
	14	45-122	77		45-55; 55-65; 65-75; 75-82; 82-92; 92-102; 112-122	7
		10-28	18		10-14; 24-28	2
Kurkachidag more	5	445-571	126		445-455; 455-465; 465-475; 475-481; 481-491; 491-501; 501-511; 511- 520; 521-531; 541-551; 551-561; 561-571	13
	7	625-790	165		625-630; 780-790	2
Yashma more	5	38-203	165		38-48; 48-55; 55-62; 62-72; 72-82; 82-92; 92-102; 102-112; 112-122; 122-132; 132-142; 142-152; 152-163; 163-173; 173-183; 183-203	17
Shurabad more	17	23-184	161		23-32; 59-68; 68-77; 77-86; 86-93; 99-102; 102-111; 134-144; 166-175; 175-184	10
	14	122-155	33		122-132; 132-142; 142-155	3
	6	545-604	59		545-555; 566-574; 574-584; 584-590; 590-595; 595-601; 601-604	7
Kurkachidag more	5	571-636	65	Sarmatian	571-576; 576-586; 586-596; 596-606; 606-616; 616-626; 626-636	7
		790-866	76		790-800; 850-860; 860-866	3
İsland Chilov	8	877-962	85		877-880; 955-962	2
Sangachal-Duvanni-Hara Zira	19	3665-3918	253		3665-3670; 3910-3918	2
Neft Dashlary	355	1483-1502	19		1483-1487; 1495-1502	2

Continuation of table 3

Azerbaijan sector of Caspian sea						
Structure	Well №	Interval in m.	Thick-ness in m.	Age	Interval of sampling	Number of samples
Pirallahi Adasi	425	790-864.3	74.3	Sarmatian	790-795; 850-855; 860-864.3	3
Pirallahi Adasi	432	1120-1135	15		1120-1125; 1130-1135	2
Pirallahi Adasi	433	626-647	21		626-630; 645-647	2
Pirallahi Adasi	435	1110-1130	20		1110-1115; 1125-1130	2
Yashma more	5	203-363	160		203-213; 213-223; 223-233; 233-243; 243-253; 253-263; 263-273; 273-283; 283-293; 343-353; 353-363	11
Shurabad	14	155-204	49	karaganian	155-164; 164-174; 174-184; 184-194; 194-204	5
Kurkachidag	5	636-666	30		636-646; 646-656; 656-666	3
	7	866-921	55		866-877; 877-886; 886-897; 897-906; 907-910; 915-921	6
Yashma more	5	370-385	15		370-378; 378-385	2
Apsheeron Bank	6	1508-1517	9	Conkian+Karaganian	1508-1515; 1515-1517	2
	34	698-939	241		698-705; 800-810; 930-939	3
	37	588-766	178		588-598; 600; 610; 760-766	3
	41	994-1155	161		994-1000; 1150-1155	2
İsland Chilov	6	880-896	16		880-890; 890-896	2
	4	805-810.5	5.5		805-810.5	1
	17	58.2-204.5	146.3		58.2-63; 200-204.5	2
Yuzhnaya	155	0.5-70	69.5		0.5-10; 60-70	2
Guneshli	1	4255-4260	5		4255-4260	1
	37	658-766	108		658-663; 760-766	2
Zhliloy island	4	805-810.5	5.5		805-810.5	1
Apsheeron Bank	37	787-810	23		787-797; 797-810	2
	80	986-1030	44		986-1000; 1020-1030	2
Yasma more	5	385-414	29	Chokrakian	385-395; 395-404; 404-414	3
Kurkachidag	5	684-728	44		684-688; 688-694; 698-705; 719-728	4
	7	921-962	41		921-932; 932-940; 940-951; 951-962	4
Shurabad	14	213-241	28		213-223; 229-231; 231-241	3
	17	214-223	9		214-223	1
North-Apsheeron	6	604-659	55	Tarkhanian-Chokrakian	604-606; 606-613; 647-659	3
	1	2125-2164	39		2120-2125; 2158-2164	2
	4	2250-2650	400		2250-2255; 2645-2650	2
	3	1995-2116	121		2250-2255; 2645-2650	2
Khazri	1	3078-3375	297		3078-3088; 3200-3210; 3365-3375	3
Island Chilov	7	204.5-262	57.5		204.5-210.5; 255-262	2
Kirmaku coastal	1134	360-550	190		360-365; 545-550	2
Kirmaku coastal	1502	420-486	66		420-430; 480-486	2
Sangachal-Duvanni-Hara Zira	550	4800-4898	98		4800-4810; 4890-4898	2
	534	4426-4900	474		4426-4431; 4890-4900	2
Apsheeron Bank	41	1150-1155	5	Maykopian	1150-1155	1
Guneshli	37	810-899	89		810-820; 890-899	2
İsland Chilov	7	280.5-504	223.5		280.5-290; 500-504	2
Paleo-Volga	1	1381-2249	868		1381-1388; 1400-1405; 1425-1430; 1445-1450; 1466-1469; 1530-1587; 1600-1607; 1623-1635; 1658-1663; 1692-1699; 1717-1724; 1746-1753; 1770-1777; 1820-1827; 1842-1849; 1864-1871; 1886-1893; 1908-1915; 1925-1930; 1945-1956; 1967-1974; 1984-1991; 2000-1005; 2020-2025; 2030-2035; 2055-2060; 2075-2080; 2095-2100; 2121-2168; 2204-2211; 2226-2232; 2246-2249	32

Continuation of table 3						
Azerbaijan sector of Caspian sea						
Structure	Well №	Interval in m.	Thickness in m.	Age	Interval of sampling	Number of samples
Arzu	2	3201-3206	5	Maykopian	3201-3206	1
Apsheron bank	41	1190-1233	43		1190-1200; 1223-1233	2
Neft Dashlari	478	616-628	12		616-625; 625-628	2
Sangachal more	550	5010-5775	765		5010-5020; 5500-5510; 5770-5775	3
	551	3850-4000	150		3850-3860; 3990-4000	2
Shurabad more	14	250-441	191		250-260; 358-368; 378-388; 395-403; 403-412; 412-423; 431-441	8
	6	659-791	132		659-671; 680-689; 689-697; 697-705; 705-713; 713-728; 728-735; 735-749; 749-758; 758-767; 767-771; 771-776; 785-791	13
	17	271-362	121		271-280; 289-299; 299-309; 309-320; 341-351; 351-362	6
Kurkachidag	5	734-906	172		734-744; 754-764; 764-775; 775-785; 795-805; 805-815; 815-825; 840-850; 850-860; 860-864; 864-874; 905-906	12
	7	962-1385	423		962-971; 971-982; 982-992; 992-1001; 1011-1021; 1021-1031; 1031-1039; 1039-1046; 1046-1054; 1054-1064; 1064-1074; 1084-1093; 1093-1100; 1100-1113; 1113-1124; 1124-1134; 1135-1145; 1155-1165; 1165-1175; 1185-1195; 1204-1211; 1213-1226; 1226-1235; 1235-1245; 1257-1269; 1269-1282; 1282-1295; 1308-1317; 1317-1321; 1321-1331; 1331-1341; 1341-1351; 1351-1363; 1363-1373; 1379-1385	35
Neft Dashlary	380	439-1000	561	Paleogene	439-445; 500-510; 700-710; 990-1000	4
Yashma more	5	414-810	396		414-424; 424-434; 434-444; 444-453; 453-461; 464-475; 475-486; 510-520; 530-540; 540-550; 550-560; 560-570; 570-580; 590-596; 630-643; 655-665; 675-686; 686-698; 698-703; 709-721; 721-731; 731-741; 741-755; 755-766; 766-777; 777-787; 787-791; 794-805; 805-810	29
Yashma more	5	810-871	61		810-820; 820-828; 828-838; 838-848; 848-858; 858-869; 869-871	7
Shurabad	14	441-507	66		441-452; 452-466; 466-476; 489-499; 499-507	6
	6	791-819	28		791-799; 799-805; 815-819	3
	17	430-498	68		430-439; 487-490; 494-498	3
Kurkachidag	5	916-1037	121		916-926; 936-946; 946-954; 971-981; 989-999; 1011-1024; 1024-1037	7
	7	1385-1450	65		1385-1395; 1430-1440; 1440-1450	3

Table 4 List of studied structures, wells, and sampling intervals from the Kazakh sector of the South Caspian Sea of the South Caspian Sea						
Kazakhian sector of Caspian sea						
Structure	Well №	Interval in m.	Thickness in m.	Age	Interval of sampling	Number of samples
Skalistaya	561	2-75	73	Meotian	2-15; 15-30; 30-45; 45-60; 60-75	5
Skalistaya	578	3-40	37	Sarmatian	3-10; 30-40	2
	564	0-80	80		0-10; 50; 60; 70-80	3
	551	0-100	100		0-5; 5-10; 20-30; 50-60; 60-70; 70-80; 80-90; 90-100	8
	541	10-40	30		10-12; 20-30; 30-40	3
	542	20-90	70		20-30; 50-60; 60-70; 70-80; 80-90	5
	552	0-100	100		0-5; 5-10; 10-20; 20-30; 30-40; 40-50; 50-60; 60-70; 70-80; 80-90; 90-100	11
	558	0-105	105		0-10; 10-20; 20-30; 30-40; 40-50; 50-60; 60-70; 70-80; 80-90; 95-105	10
	553	0-120	120		0-10; 10-15; 15-25; 25-35; 35-45; 45-55; 65-75; 85-95; 95-110; 110-120	10

Continuation of table 4

Kazakhian sector of Caspian sea						
Structure	Well №	Interval in m.	Thickness in m.	Age	Interval of sampling	Number of samples
Skalistaya	559	0-100	100	Sarmatian	0-10; 10-20; 20-30; 30-40; 40-50; 50-60; 60-70; 70-80; 80-90; 90-100	10
	591	20-90			20-30; 30-40; 40-50; 60-70; 70-80; 80-90	6
	590	20-90	70		20-30; 30-40; 40-50; 60-70; 70-80; 80-90	6
	578	85-115	30		85-95; 100-105; 105-115	3
	273	30-87	57		30-40; 50-60; 80-87	3
	275	0-50	50		0-10; 40-50	2
	276	40-110	70		40-50; 70-80; 100-110	3
	277	0-75	75		0-10; 50-60; 65-75	3
	284	0-70	70		0-10; 50-60; 60-70	3
	285	0-95	95		0-10; 60-70; 85-95	3
	286	5-25	20		5-10; 20-25	2
	287	10-50	40		10-20; 40-50	2
	294	0-90	90		0-10; 70-80; 80-90	3
	295	0-105	105		0-10; 70-80; 100-105	3
	296	0-101	101		0-10; 70-80; 91-101	3
	539	12-40			12-15; 15-17; 17-20; 20-25; 25-32; 35-40	6
	560	5-100	95		5-10; 10-20; 20-30; 30-40; 40-50; 50-60; 70-80; 80-90; 90-100	9
	566	5-120	115		5-15; 15-25; 25-35; 35-45; 45-55; 55-65; 65-75; 75-85; 90-105; 105-120	10
	565	0-110	110		0-10;10-20;20-30;30-40;40-50; 60-75;75-85;90-100; 100-110	9
	563	10-70	60		10-20; 20-30; 30-40; 40-50; 50-60; 60-70	6
	567	3-110	107		3-15; 15-25; 25-35; 35-45; 45-60; 60-70; 70-80; 80-95; 95-110	3
	568	20-100	80		20-30; 30-40; 40-50; 50-60; 60-70; 70-80; 80-90; 90-100	8
	548	20-110	90		20-30; 30-40; 40-50; 50-60; 60-70; 70-80; 80-90; 90-100	8
	545	0-110	110		0-2.5; 2.5-5; 5-15; 15-25; 25-35; 35-45; 55-65; 65-75; 75-85; 85-95; 95-110	11
	550	9-40	31		9-12; 12-14; 14-16; 18-20; 20-25; 25-30; 30-40	7
	547	0-70	70		0-3;20-30; 30-40; 40-50; 50-60; 60-70	6
	556	0-110	110		0-10; 10-20; 20-30; 30-40; 40-50; 50-60; 60-70; 70-80; 80-90; 90-100; 100-110	11
	555	0-120	120		0-15; 15-30; 30-45; 45-60; 60-75; 75-90; 90-105; 105-120	8
Rakushechnoe more	265	100-110	10	Sarmatian	100-110	1
	281	0-110	110		0-10; 40-50; 100-110	3
	282	0-100	100		0-10; 20-30; 70-80; 90-100	4
	297	0-60	60		0-10; 40-50; 50-60	3
	298	5-105	100		5-10; 60-70; 100-105	3
	278	0-100	100		0-10; 50-60; 90-100	3
Sagindig	271	65-90	25		65-75; 80-90	2
	273	0-75	75		0-10; 60-70; 70-75	3
	274	20-70	50		20-30; 60-70	2
	288	0-12	12		0-5; 5-12	2
	290	0-28	28		0-5; 20-28	2
	293	0-5	5		0-5	1
	291	34-54	20		34-44; 44-54	2
Melovoy More	260	40-80	40		40-50; 70-80	2
	259	70-85	15		70-75; 80-85	2
Skalistaya more	539	40-100	60	Conkian	40-50; 50-60; 60-70; 70-80; 80-90; 90-100	6
	547	80-100	20		80-90; 90-100	2
	1	1300-1444	144		1300-1310; 1390-1400; 1434-1444	3

Continuation of table 4						
Kazakhian sector of Caspian sea						
Structure	Well №	Interval in m.	Thickness in m.	Age	Interval of sampling	Number of samples
Skalistaya	547	100-110	10	Karaganian	100-110	1
	591	50-90	40		50-60; 80-90	2
Skalistaya more	7	220-635	410	Chokrakian	220-230; 300-310; 500-510; 600-610; 630-635	5
	5	180-605	10		180-190; 250-260; 500-510; 600-605	4
Skalistaya more	7	220-635		Maycop	220-230; 280-290; 337-347; 372-382; 414-424; 453-463; 492-502; 528-538; 570-580; 623-635	10
	1	1300-1444			1300-1310; 1310-1320; 1320-1330; 1330-1340; 1340-1350; 1392-1400; 1432-1444	7
	529	70-100	30		70-80; 80-90; 90-100	3
	5	180-605	425		180-190; 221-231; 288-298; 403-413; 449-460; 478-488; 515-525; 530-540; 595-605	9
	3	143-605			143-153; 250-260; 350-360; 400-440; 424-434; 434-444; 453-463; 528-538; 562-572; 595-605;	10
Skalistaya more	7	635-672		Paleogen	635-645; 645-655; 666-672	3
	3	635-1055			635-645; 744-757; 757-767; 878-880; 905-945; 938-948; 971-980; 1011-1021; 1045-1055;	9
Skalistaya more	7	744-755		Cretaceous	744-755	1

with the open ocean. As a result, the Caspian Basin experienced episodic isolation, leading to anoxic conditions and variable salinity regimes. The isolation of the Caspian Sea, caused by a combination of intensified uplift of the Greater Caucasus and tectonic subsidence in the South Caspian Basin, began around 5 Ma and restricted its connectivity with the Black Sea.

South Caspian Basin, depositing up to 7 kilometres of fluvial, deltaic and lacustrine clastic sediments in the basin centre [7]. The formation of the deltaic successions of the Productive Series is suggested to be related to the sea level drop during the climax of the Messinian salinity crisis (MSC)

at 5.6 Ma, causing the isolation of the Caspian Sea [8]. Other models advocate large-scale plate tectonic causes, related to a regional reorganisation in the Arabia-Eurasia collision [9].

Major unconformities occur:

- at the base of Lower Miocene strata
- at the base of Lower Pliocene strata
- at the base of Middle Pliocene strata

The Miocene stratigraphic succession in the basin generally includes the following horizons: Tarkhanian, Chokrakian, Karaganian, Konkian, Sarmatian, Meotian, and Pontian. These deposits consist mainly of clays, marls, sandstones, and siltstones, often containing abundant microfauna (table 5).

Lithostratigraphy of Miocene deposits

The only complete Miocene stratigraphic section without significant depositional breaks is exposed on the eastern slope of Mount Islamdag in Central Gobustan, Azerbaijan, with a total thickness of approximately 500 m. A continuously exposed interval of more than 105 m within the section records a transition from deep-marine, low-energy clay-rich deposits, interpreted as outer shelf to slope facies, to coarsening-upward proximal sediments, reflecting progressive shallowing of the basin and deltaic progradation [12]. In total, about 26 Oligocene–Miocene outcrops have been identified within the Shamakhi–Gobustan onshore hydrocarbon province (fig. 4). However, these outcrops do not include all stratigraphic subdivisions of the Oligocene–Miocene succession. This limitation is mainly due to poor exposure conditions and difficulties in distinguishing detailed subdivisions of the Middle and Upper Miocene diatomaceous deposits.

The lithostratigraphic scheme presented here illustrates the general lithology and microfauna content of offshore Miocene deposits. Meotian deposits are represented by grey clays with interlayers of laminated shales, brecciated dolomites, oolitic limestones, and conglomerates. Sarmatian deposits consist mainly of dense laminated grey clays with a higher proportion of sandy material. Konkian deposits are characterised by

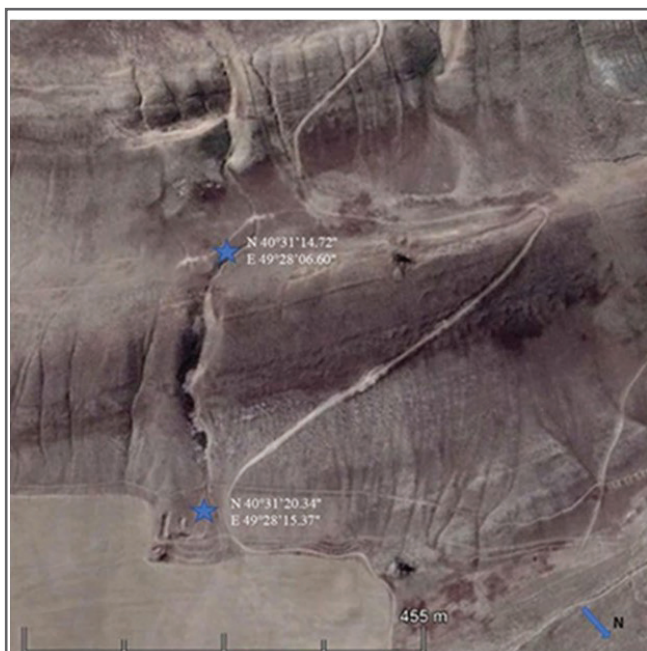


Fig. 4. Onshore Azerbaijan. Gobustan area, Eastern slope of the Islamdag mountain. Outcrop of Oligocene – Miocene. Total thickness 500 m. 26 Oligocene-Miocene outcrops in onshore Azerbaijan (Shamakha-Gobustan HC province)

The stratigraphy summary of Neogene-Quaternary deposits of the South Caspian basin (modified after [4], chronostratigraphy, magnitostratigraphy after [10] in [11])														Table 5										
System	Subsystem	Stage	Part	Unit	Alps	Stage/Horizon/subhorizon		Caspian sea basin Thickness in m.	Ma Age	Source rock	Reservoir rocks	Seal	HC											
Quaternary	Pleistocene	Upper	Tarantiy	upper	Wurm	Recent		5-1200	0.006-0.01															
						Novo Caspian			0.10															
			Mid			Iony	Khvalinian		0.25-0.3															
		Bakunian		0.80-1.1																				
		Lower	Calabrian	Eopleistocene	lower	Gunz-Minde	Gunz		Apsheronian					10-1000	1.8-2.2									
														Akchagilian	0-500	2.5-3								
		Upper	Gelasiy- Plasencian		Zandean	Productive/ Red series	up to 6000		3.8-5.5															
			Lower																					
		Miocene		Upper	Messinian														Pontian		10-160	5.8		
			Miocene upper																Diatomian layers	Meotian	35-130	8.8		
Sarmatian	10-80							13.6																
Mid (Badenian)	Sarmatian		Konkian	20-25	14.3																			
			Karaganian	10-75	15.8																			
Paleogene	Miocene	Upper	Tortonian +Serravaliy					Spirialis layers		10-50	17													
								Helvetian + Langian		Tarkhanian	30							17.2						
										Lower	Burdigalian									upper Maycop		70-250	24.6	
		Oligocene	lower Maycop																					
		Eocene	Eocene	Foamifer layer	Koun	140-250																		

interbedded clays and sands with relatively rare conglomerate layers, whereas Karaganian deposits contain clays intercalated with more abundant sandstones and sands.

Tarkhanian deposits are predominantly clayey and contain only minor sandstone and marlstone interbeds. In contrast, Chokrakian deposits consist mainly of dark grey clays interbedded with dolomite layers and frequently contain abundant fish remains. The presence of dolomite interlayers indicates a reduced supply of terrigenous material and suggests relatively calm depositional conditions within the Chokrakian Basin. (Supplementary file) figure 5.

A similar generalized lithostratigraphic scheme was drawn for the Turkmenian sector of the Caspian Sea based on 2 studied structures, where only Sarmatian Tarkhanian-Chokrakian and Upper Maykopian deposits of the Lower Miocene were identified. The Upper Maykopian deposits of the Lower Miocene consist of non-carbonate dark grey, clay lithologies containing abundant scale fragments, fish teeth, foraminifera, and very rare ostracods. Tarkhan-Chokrakian deposits consist of limestones lithology with interlayers of fine-grained sand, clay, and marl containing oolites and pyrites. In the upper part of the Chokrakian deposits, we found abundant fish fragments along with Pelecypods and Gastropoda. There were also foraminifera with very rare Ostracoda. Sarmatian deposits consist of sandy clay formations. At the very bottom of the Sarmatian, there is oolitic limestone containing characteristic foraminifera and some ostracods. Supplementary file, figure 6.

In Kazakhstan several deep exploration wells penetrating the Paleogene and Cretaceous sections were studied. Supplementary file, figure 7.

4. Microfaunal assemblages and their paleoecological significance

Micropaleontological analysis revealed diverse microfaunal assemblages within the Miocene deposits [5, 13]: Foraminifera: 39 genera and 95 species. Foraminifera occur relatively frequently throughout the studied wells and represent the most common microfaunal group. Ostracods: 12 genera and 40 species. A total of 53 ostracod species were identified in Miocene and Pontian deposits, mainly belonging to the families Cypridae and Cytheridae. Dominant genera include: *Leptocythere*; *Loxoconcha*; *Xestoleberis*; *Cythereis*; and other micro remains.

Additional microfossils found in the studied samples include: fish otoliths; radiolarians; charophytes (*Chara*); *Ovulites*; juvenile gastropods and pelecypods. Notably, ostracods are generally absent in Maykopian deposits, where stratigraphic correlation is mainly based on foraminifera and lithology. The taxonomic identification of ostracods and foraminifera was carried out using several atlases and published studies devoted to Miocene deposits [4, 8, 13-19].

4.1. Distribution of microfauna by sector

By Azerbaijani sector

A total of 375 core samples from 48 wells were analyzed. The wells penetrated the following stratigraphic units: Pontian; Meotian; Sarmatian; Konkian; Karaganian; Chokrakian; Tarkhanian; Maykopian; Paleogene. In most drilled well sections in Caspian offshore the Pontian deposits are unconformably overlain by Late Pliocene Akchagylian and Pleistocene Apsheronian deposits. Ostracods are most commonly found

in Pontian and Sarmatian deposits, while they are absent in Maykopian strata. Supplementary files table 6-10.

Spiralis-bearing layers within the Miocene deposits are represented by Chokrakian and Tarkhanian sediments. The ostracod fauna is generally more abundant in the Chokrakian deposits than in the Tarkhanian deposits. It should be noted that most of these ostracod species have a relatively wide regional distribution within the Caspian Basin, except *Leptocythere kopetdagica*, which was identified only in wells from the Turkmen sector of the South Caspian Basin. This species was not found in other sectors of the basin.

Several ostracod species, such as *Cythereis tschokrakensis* and *Limnocythere tschokrakensis*, together with associated foraminifera including *Bolivina tarchanensis* and *Sigmolina tschokrakensis*, serve as important biostratigraphic indicators and allow a clear distinction between Chokrakian and Tarkhanian deposits.

The ostracod fauna of the Konkian and Karaganian sediments is relatively poor in species diversity and is represented by only two or three taxa, including *Leptocythere karaganica*, *Cythereis gracilis*, *Xestoleberis lutrae*, and *Darwinula stevensoni*. These deposits generally contain a low abundance of ostracods, and foraminifera are also relatively scarce, except *Cibicides lobatulus*, which occurs more frequently.

In the Sarmatian sediments of the South and Middle Caspian sections, the ostracod fauna is dominated by species of the genus *Leptocythere*. Like other Miocene intervals, ostracods in Sarmatian deposits are generally low in abundance. Among foraminifera, species of the genera *Elphidium* and *Parasponion* occur more frequently than other taxa. The Sarmatian microfaunal assemblages are also associated with abundant remains of *Ovulites sarmaticus* and *O. renata*, as well as juvenile pelecypods and gastropods, together with numerous fish bones and scales. The ostracod distribution within Meotian sediments reflects several patterns related to basin evolution and faunal migration. In the studied offshore well sections, the difference between the late Meotian and Pontian ostracod assemblages is clearly recognisable. In the lowermost part of the Meotian section, environmental conditions were likely anoxic to dysoxic, as indicated by the scarcity of benthic microfossils and the abundance of fish remains. Several ostracod species, including *Cypris gigas*, *Xestoleberis meotica*, *X. ovata*, and *Loxoconcha meotica*, disappear from the record and are absent during the Pontian stage.

In Pontian deposits, in addition to other ostracods and particularly members of the *Leptocytheridae*, typical Pontian species such as *Bacunella dorsoarcuata* [20] and *Pontoniella loczyi* were identified, although their shells are generally less ornamented. Benthic foraminifera are rare in these deposits and, similar to the ostracods, were most likely transported from more oxygenated marginal parts of the basin.

By Turkmen Sector

Miocene deposits were identified in two structures: Sue and Bekdash. Two main horizons were recognised: Sarmatian and Tarkhanian-Chokrakian. Ostracods are rare in these deposits and absent in the Maykopian strata. Supplementary file table 11.

By Kazakh Sector

Miocene deposits were studied in four structures, with a total of 324 samples from 55 wells. Recognised stratigraphic units include: Meotian, Sarmatian, Konkian, Karaganian, and Chokrakian. In this sector, foraminifera occur frequently,

while ostracods are mainly present in Sarmatian and Meotian deposits. Supplementary file table 12-14

Besides ostracoda and foraminifera in Miocene deposits

were found in some other microfauna like otoliths, radiolaria, chara, ovulites, and some juvenile forms of pelecypod and gastropod.

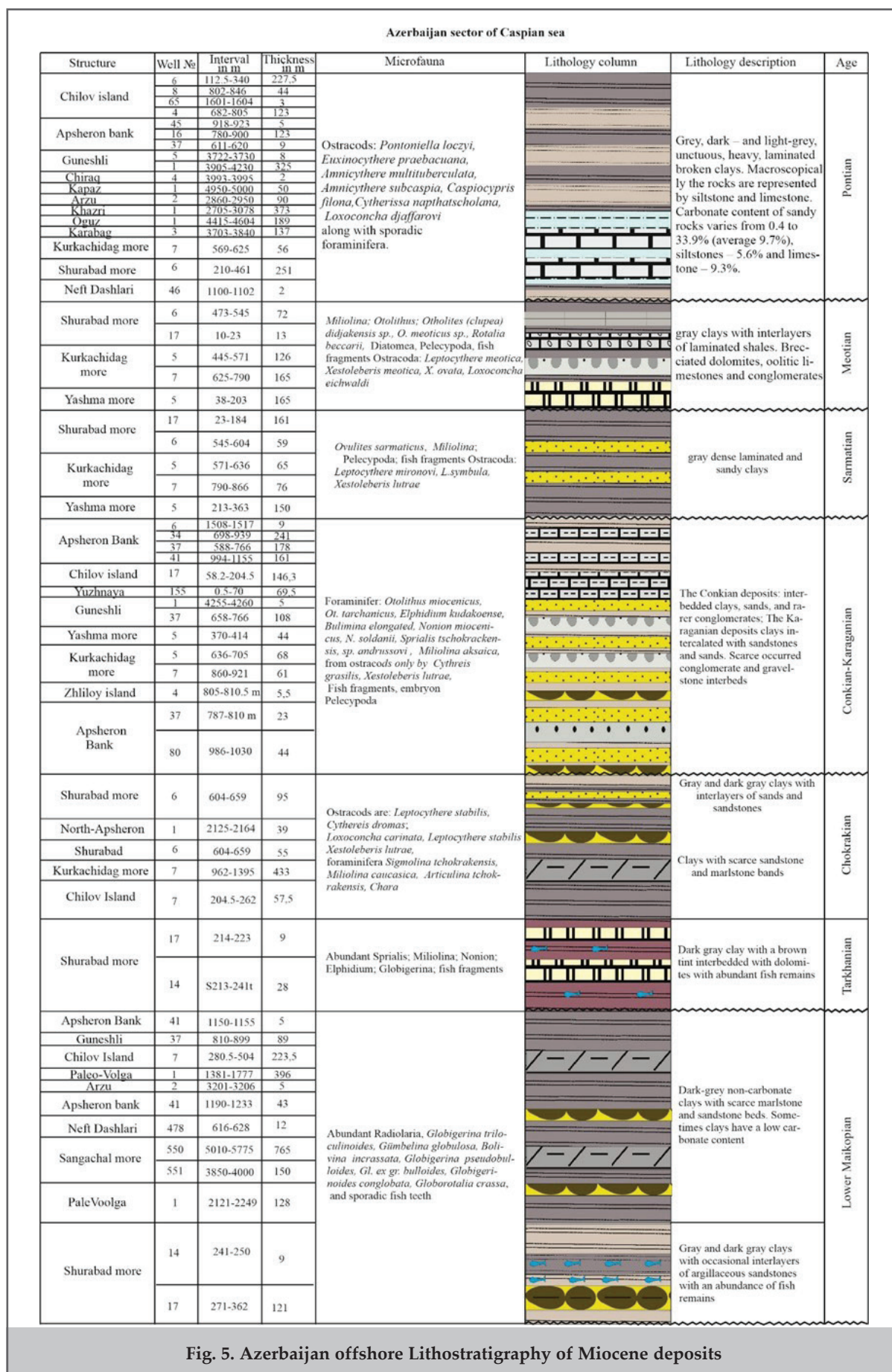


Fig. 5. Azerbaijan offshore Lithostratigraphy of Miocene deposits

Fig. 7. Kazakhstan offshore Lithostratigraphy of Miocene deposits

Karakum sector of Caspian sea

Structure	Well №	Interval m	Thickness m	Macro and micro fauna	Lithology column	Lithology description	Age
Skalskaya	561	5-75	73	<i>Modiola volly-</i> <i>nica var minor</i> ; <i>Ervilla minima</i> ; <i>Dostinia mae-</i> <i>olica</i> , <i>Tapes cir-</i> <i>rus</i>	Ostracoda: <i>Xestoleberis maotica</i> , <i>X. larvae</i> , <i>X. ovata</i> , <i>Leptocythere</i> <i>maotica</i> , <i>L. striatocostata</i> , <i>Loxoco-</i> <i>cha maotica</i> , <i>Foraminifera</i> <i>Quin-</i> <i>quelocina sepioliana</i> , <i>Q. cf.</i> <i>quadrilongor</i> , <i>Ochellus</i>	Limestones and clays locally oolitic limesto- nes	Meotian

Fig. 6. Turkmenistan offshore Lithostratigraphy of Miocene deposits

Structure	Well №	Interval in m	Thickness in m	Microfauna	Lithology column	Lithology description	Age
Beckdash more	122	10-130	120	Foraminifera: <i>Quinqueloculina consobrina</i> , <i>Atricularia problema</i> , ostracoda: <i>Trachyleberis kolesnikovii</i> , <i>Lepidocythere symbula</i> , <i>Laxocochlea impressa</i> , <i>Ophidolina</i> (gobius) <i>sarmaticus</i> .		Gray and light gray clays and silts	
	123	0-100	100				
	288	0-80	80				
	101	0-65	65				
Sue more	102	0-45	45			Sandy clay formations: in the very bottom of sarmatian colluvium limestone	Sarmatian
	103	0-90	90				
	107	0-101	101				
	111	0-110	110				
	112	0-120	120				
	113	0-110	110				
	115	0-125	125				
	116	0-125	125				
	117	0-115	115				
	118	0-125	125				
	119	0-125	125	Ostracoda: <i>Lepidocythere minorovi</i> , <i>L. saluta</i> , <i>L. marginata</i> , <i>Trachyleberis sarmatica</i> , <i>Laxocochlea bairdyi</i> .			
	120	0-101	101	Foraminifera: <i>Elphidium macellum</i> , <i>E. regina</i> , <i>E. crispum</i> , <i>Nonion markobi</i> , <i>Porosonion granosum</i> et al as well as fish fragments, <i>Ovulites sarmatica</i> .			
	121	0-130	130				
	122	0-120	120				
	123	0-120	120				
	124	0-118	118				
Sue more	125	0-80	80				
	127	0-100	100				
	303	0-110	110				
	304	0-135	135				
	305	12-75	63				
	426	10-130	120				
	427	16-81	65				
	428	5-50	45				
	429	6-61	55				
	427	106-116	10	In the top of Chokrakian a lot of fish fragments along with pelocypoda and gastropoda. From foraminifera: <i>Quinqueloculina akneria</i> , <i>Cibicides ex gr lobatulus</i> , <i>Flutillus boucaumi</i> , <i>Elphidium rigosum aschianensis</i> , Ostracoda: <i>Cythereida milleri</i> , <i>Trachyleberis elegantissima</i> , <i>Laxocochlea carnata</i> , <i>Limonocythere ischokrakensis</i>		Limestones are whitish gray with a darkish tinge with interlayers of dark gray and fine grained sand and gray and dark green clay and marl with a bluish green tint, highly carbonate. Includes oolites and pyrites	Chokrakian
	428	95-125	30	Foraminifera: <i>Spiraloculina cf plana</i> , <i>Sigmoilina ischokrakensis</i> , <i>S. ischokrakensis koubasensis</i> , <i>Quinqueloculina akneriana buloides</i> , <i>Q. akneriana longa</i> , <i>Q. caucasicola</i> , <i>Leontulina</i> sp., <i>Rosalina beccarii</i> , <i>R. irinaensis</i> sp. nov., <i>Elphidium rigosum aschianensis</i> , <i>Bilaminia tarconensis</i> , Ostracoda: <i>Limonocythere ischokrakensis</i> , <i>Cythereida milleri</i>			
	429	86-106	20				
Beckdash more	287	0-110	110				
	405	190-110	10	Foraminifera: <i>Quinqueloculina akneriana</i> , <i>Q. akneriana rotunda</i> , <i>Q. cf circularis</i> , <i>Flutillus boucaumi</i> , <i>Sigmoilina ischokrakensis</i> ,			
Beckdash more	405	190-110	10			Non-carbonate dark gray, gray clays with a lot of scale bones, fish teeth	Upper Maykopian suite

Gray and light clays

Silt

Sandy clay formation

Oolite limestone

Sand

Clayey limestone

Oolites

Pyrites

Scale bones, fish testilimestones

Age		Meotian										Sarmatian					Karaganian					Chokrakian (Spiralis layers)					Maycopian					Koun				
Number of samples	Depth	4	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21	23	31	34	35	36	39	40	41	42	43	44								
Name of fauna		45-55	65-75	75-82	82-92	92-102	122-132	132-142	142-155	155-164	164-174	174-184	184-194	194-204	213-223	229-231	231-241	250-260	358-368	395-403	403-412	412-423	441-452	452-466	466-476	480-489	489-499	499-507								
<i>Globigerina bulloides</i>		xx																																		
<i>G.triloculinoides</i>																		x																		
<i>G.compressa</i>																																				
<i>Globigerinella voluta</i>		x																																		
<i>G. aspera</i>																																				
<i>Globorotalia canariensis</i>																																				
<i>G. crassaformis</i>																																				
<i>Gyroidina exculpta</i>																																				
<i>Elphidium macellum</i>		x																																		
<i>Eponides umbonatus</i>																																				
<i>Cibicides midwayensis</i>																																				
<i>C. lobatulus</i>													x																							
<i>Rotalia beccarii</i>		x			x								x																							
<i>Porosonion granosum</i>		x																																		
<i>N. micrus</i>																																				
<i>Radiolaria</i>		x																																		
<i>Miliolina sp</i>		x																																		
<i>Spiralis sp</i>				x																																
<i>Pelecypoda</i>																																				
<i>Otholithus</i>																																				
Fish bone		xx	xxx	xx	xx	xxx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xx	xx	xx		xxx	xx	xxx	xx	xxx	xx	xx	x	x								
fish scales																																				
Fish teeth																																				
Embryo macrofauna		xx																																		
from other microfauna																																				
<i>Ovulites sarmatica</i>																																				
Ostracoda		x				x																														
<i>Lepocythere meotica</i>																																				
<i>L. karaganica</i>																																				
<i>Euxionocythere suzini</i>				x																																
<i>Cypris gigas</i>																																				
<i>C. dromas</i>																																				
<i>Xestoleberis lutrae</i>																																				
<i>Cyprideis littoralis</i>																																				
<i>Cythereis sarmatica</i>																																				
<i>Loxoconcha bairdyi</i>																																				
<i>Cytheridea mulleri</i>																																				
Legend:		x	rare (1-5)				xx	seldom (5-10)		xxx	usually (10-20)	abundant (<100)																								

Continuation of table 7																																										
Age		Upper maycopian																																								
Number of samples		962-971	97	982-992	992-1001	1001-1011	1011-1021	1021-1031	1031-1039	1039-1046	1046-1054	1054-1064	1064-1074	1084-1093	1093-1100	1100-1113	1113-1124	1124-1134	1135-1145	1155-1165	1165-1175	1185-1195	1204-1211	1213-1226	1226-1235	1235-1245	1257-1269	1269-1282	1282-1295	1308-1317	1317-1321	1321-1331	1331-1341	1341-1351	1351-1363	1363-1373	1430-1440	1440-1450				
Name of fauna																																										
<i>Globigerina bulloides</i>																																										
<i>G. corpulenta</i>																																										
<i>G. conglobatus</i>																																										
<i>Globorotalia pseudoscutilla</i>																																										
fish bone		xx	xx	xxxx	xx	xx	xx	xx	xxxx	xxxx	xxxx	xxxx	xx	xx	xx	xx	xxxx	xxxx	xxxx	xx	xx	xxxx	xxxx	xxxx	xx	xx	xx	xx	xxxx	xxxx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	
fish scales			xx	xxxx	xx	xx	xx	xx	xxxx	xxxx	xxxx	xx	xx	xx	xx	xx	xxxx	xxxx	xxxx	xx	xx	xxxx	xxxx	xxxx	xx	xx	xx	xx	xxxx	xxxx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
Fish teeth		x															xx		xx	xx	xx	xx	xx	xx	xx				xx	x	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	
fish vertebrae																																										
Embryo pelecypoda																																										
<i>Chara</i>																																										
Fish fragments																																										
Legend:		x	rare (1-5)	xx	seldom (5-10)	xxx	usually (10-20)	xxxx	abundant (<100)											xx								xx	xx													

Distribution of other microorganisms in Miocene sediments of the Azerbaijan sector of the Caspian sea														Table 8	
Name of microfauna		Upper Miocene			Middle Miocene						Miocene lower		Oligocene		
		Pontian	Meotian	Sarmatian	Diatomian layers		Concian	Karaganian	Chokrakian	Spiralis layers	Tarkhanian	upper	lower		
Age		Other micro fossils													
<i>Rhabdammina</i>														x	
<i>Ovulites sarmaticus</i>			xxx	xxx										x	
<i>O. renata</i>			xx	xx	xx	xx	xx								
<i>O. gratus sp.</i>				x											
<i>Otholitis sp</i>				x					x						
<i>O. var miocenica</i>												xx			
<i>O.(Rhombus) carius</i>							xx								
<i>O.(Clupea) rostrata</i>							xx	xx							
<i>O. (Clupea) tarchanicus</i>							xx	xx							
<i>O.(Gadidarum) minusculus</i>															
<i>O.(gobius) pretiosus</i>				x											
<i>oolits</i>			xx												
<i>Radiolaria</i>			x									xx			
<i>Pelecypoda, gastropoda</i>				xx	xx	xx	xx	xx	xx						
bones scales fish teeth			xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
<i>Chara</i>												x			
<i>Discorbis sp</i>														x	
Legend:		x	rare (1-5)	xx	seldom (5-10)	xxx	usually (10-20)	xxxx	abundand (<100)						

Table 9

Distribution of Ostracod in Miocene Sediments of the Azerbaijani Sector of the Caspian Sea

		Upper Miocene		Middle Miocene				Miocene lower	Oligocene
Name of microfauna		Diatomian layers			Sprialis layers			upper	lower
Age	Pontian	Meotian	Sarmatian	Concian	Karaganian	Chokrakian	Tarkhanian	Maycopian	Maycopian
Ostracoda:									
<i>Bacuniella dorsoarculata</i>	x								
<i>Caspiocypris ex gr filona</i>	x								
<i>Pontoniella loczyi</i>	x								
<i>Amnocythere subcaspia</i>	x								
<i>A. quinquetuberculata</i>	x								
<i>A. multituberculata</i>	x								
<i>A. palimpsesta</i>	x								
<i>A. saluta</i>	x								
<i>Euxinocythere (Maetocythere) praeacuana</i>	x								
<i>E.(M) bacuana</i>	x	x							
<i>E(M) praeacuana</i>	x	x							
<i>E. bosqueti</i>	x		x						
<i>E. suzini</i>	x	x	x						
<i>Tyrrhenocythere azerbaijanica</i>	x	x							
<i>Gryptocyprideis bogatchovi</i>	x								
<i>Cytherissa naphthachalona</i>	x								
<i>Cyprideis torosa</i>			x						
<i>C. punctulata</i>			x						
<i>Cypris gigas</i>		x	x						
<i>Xestoleberis meotica</i>		x							
<i>X. ovata</i>		x							
<i>X. lutrae</i>	x	x	x	x	x	x	x		
<i>Leptocythere meotica</i>		x							
<i>L. striatocostata</i>	x	x							
<i>L. karaganica</i>			x		x				
<i>L.kopetdagica</i>			x						
<i>L. stabilis</i>			x			x			
<i>L. mironovi</i>			x						
<i>L. cymbula</i>	x	x	x						
<i>L. saluta</i>			x						
<i>L.lata</i>	x								
<i>L.quinquetuberculata</i>	x	x							
<i>L. microlata</i>	x								
<i>L. marginata</i>			x						
<i>Tracyleberis kolesnikovii</i>			x						
<i>Tr. elegantissima</i>						x	x		
<i>Cythereis gigas sp nov</i>						x			
<i>C. tschokrakensis</i>						x			
<i>C. grasilis</i>		x		x	x				
<i>C. dromas</i>			x			x			
<i>C. sarmatica</i>		x	x						
<i>C. spinulosa</i>			x			x			
<i>Limnocythere tschokrakensis</i>						x	x		
<i>Loxoconcha carinata</i>						x			
<i>L.djaffarovi</i>	x					x			
<i>L. maeotica</i>		x							
<i>L.carinata alata</i>						x			
<i>L. aff. bairdyi</i>						x			
<i>L. eichwaldi</i>	x	x							
<i>L. impressa</i>			x						
<i>L. aff truncata</i>			x						
<i>Cytheridea mülleri</i>						x	x		
<i>Darwinula stevensoni</i>	x				x				

No ostracods found

No ostracods found

Table 10

Distribution of Foraminifera in Miocene Sediments of the Azerbaijani Sector of the Caspian Sea

Name of microfauna Foraminifera	Age	Upper Miocene		Middle Miocene				Miocene lower	Oligocene
		Pontian	Diatomian layers			Spiralis layers		upper	lower
			Meotian	Sarmatian	Concian	Karaganian	Chokrakian	Tarkhanian	Maycopian
<i>Spiralis andrussovi</i>							x		
<i>Stilostomella consobrina</i>				x					
<i>Anomalina affinis</i>								x	
<i>Ammodiscus sp</i>								x	
<i>A. miocenicus</i>								x	x
<i>Corcolides sp</i>									
<i>Gyroidina soldanii</i>								x	
<i>G.exclupta</i>									x
<i>G.caucasica</i>									x
<i>Globigerina bulloides</i>			xx			xx	xx	xx	x
<i>G. pseudobulloides</i>								x	
<i>G.triloculinoides</i>								xxx	xxx
<i>Globorotalia ex gr canariensis</i>								xx	xx
<i>G. crassaformis</i>									xx
<i>G.compressa</i>								xxx	xxx
<i>G. crassa</i>							xxx	xx	
<i>Globigerinella voluta</i>			xxx					xxx	xxx
<i>G.micro</i>									
<i>G. aspera</i>								xx	xx
<i>Globigerinoides conglobata</i>								x	
<i>Globotruncana linnei</i>								x	
<i>G. marginata</i>							xx	x	
<i>G. rosetta</i>								x	
<i>Globoturborotalita woodi</i>								x	x
<i>Gümbelina globulosa</i>								x	x
<i>Eponides umbonatus</i>									xx
<i>E. trümpyi</i>									x
<i>E. chalilovi</i>									x
<i>E.rependus</i>									x
<i>E. tenera</i>									x
<i>Miliolina seminulum</i>							xx		
<i>M.akneriana</i>							xx		
<i>M.aksaica</i>						x	xx		
<i>M.articulinos</i>				x					
<i>M. sp</i>			x	x		x			
<i>Spiroplectammina carinata</i>							x	x	
<i>S.carinata oligocenica</i>							x	x	
<i>S. cf. abbreviata</i>							x	x	
<i>Quinqueloculina aknericana</i>							x	x	
<i>Q. triangularis</i>				x			x	x	
<i>Q. boucana</i>							x	x	
<i>Q. consobrina</i>				x	x				
<i>Q. regularis</i>				x					
<i>Q. sp</i>				x					
<i>Bolivina tarchanensis</i>							xx	xx	
<i>B. incrassata</i>								x	
<i>B. lcyrichi</i>									x

Continuation of table 10									
		Upper Miocene		Middle Miocene				Miocene lower	Oligocene
Name of microfauna	Age	Pontian	Diatomian layers			Spiroliis layers		upper	lower
Foraminifera			Meotian	Sarmatian	Concian	Karaganian	Chokrakian	Tarkhanian	Maycopian
<i>B. advena</i>									x
<i>Bulimina inflata</i>									x
<i>B. elongata</i>									x
<i>Uvigerina pygmaea</i>							xx	xx	
<i>U. sp</i>					x	x	x		
<i>U. ex gr proboscidea</i>								x	
<i>Cibicides lobatulus</i>						xxxx	xxxx	xxxx	x
<i>C.midwayensis</i>									x
<i>C. oligocenicus Sam</i>									x
<i>Streblus ex gr. beccarii</i>							x	x	
<i>Guttalina cf. problema</i>							x	x	
<i>G.ungaricus</i>							x	x	
<i>G.perlucidus</i>								x	
<i>Lenticulina cf hermani</i>								x	
<i>L.inornata</i>							x	x	
<i>Caucasica schishkaniskye</i>							x	x	
<i>Sigmolina tschokrakensis</i>							xx	xx	
<i>Caudina caudata</i>							x	x	
<i>Cassidulina crassa</i>				x			xx	xx	
<i>Streblus beccarii</i>				x					
<i>Articulina problema</i>				x					
<i>Parasonion granosum</i>		xxx	xx	x					
<i>P. martkobi</i>		xxx	xx	x					
<i>P. sarmaticum</i>			xx	x					
<i>Nonion ex gr. punctatus</i>			x						
<i>N. subgranosus</i>			x						
<i>N.vulgaris</i>			x						
<i>N. soldanii</i>			x					x	
<i>N.pricaspicus</i>								x	
<i>N.miocenicus</i>								x	
<i>N. micrus</i>									x
<i>N.asterius</i>					x	x			
<i>Nodosaria hispida</i>									x
<i>N.schlchti</i>									x
<i>N.adolohina</i>									x
<i>N. ambigua</i>									x
<i>Elphidium macellum</i>		xx	xx						
<i>E.umbonatus</i>									x
<i>E. crispum</i>			xx						
<i>E. djalairica</i>			xx						
<i>E. aculeatum</i>			xx						
<i>E.regina</i>			xx						
<i>Ammonia beccarii</i>		xx		x	xx				
<i>Discorbis tschokrakensis</i>						xxx			
<i>Spirorutilus mariae</i>				x		x		x	
<i>Cornuspira striata</i>			x						
<i>Spiroliis tschokrakensis</i>		x				xxx			
<i>S. andrussovi</i>		x				xxx			

Continuation of table 10									
		Upper Miocene		Middle Miocene				Miocene lower	Oligocene
Name of microfauna	Age	Pontian	Diatomian layers			Spiralis layers		upper	lower
Foraminifera			Meotian	Sarmatian	Concian	Karaganian	Chokrakian	Tarkhanian	Maycopian
<i>Spirialis andrussovi</i>							x		
<i>Stilostomella consobrina</i>				x					
<i>Anomalina affinis</i>								x	
<i>Ammodiscus sp</i>								x	
<i>A. miocenicus</i>								x	x
<i>Corcolides sp</i>									
<i>Gyroidina soldanii</i>								x	
<i>G.exclupta</i>									x
<i>G.caucasica</i>									x
<i>Globigerina bulloides</i>			xx			xx	xx	xx	x
<i>G. pseudobulloides</i>								x	
<i>G.triloculinoides</i>								xxx	xxx
<i>Globorotalia ex gr canariensis</i>								xx	xx
<i>G. crassaformis</i>									xx
<i>G.compressa</i>								xxx	xxx
<i>G. crassa</i>							xxx	xx	
<i>Globigerinella voluta</i>			xxx					xxx	xxx
<i>G.micro</i>									
<i>G. aspera</i>								xx	xx
<i>Globigerinoides conglobata</i>								x	
<i>Globotruncana linnei</i>								x	
<i>G. marginata</i>							xx	x	
<i>G. rosetta</i>								x	
<i>Globoturborotalita woodi</i>								x	x
<i>Gümbelina globulosa</i>								x	x
<i>Eponides umbonatus</i>									xx
<i>E. trümpyi</i>									x
<i>E. chalilovi</i>									x
<i>E.rependus</i>									x
<i>E. tenera</i>									x
<i>Miliolina seminulum</i>							xx		
<i>M.akneriana</i>							xx		
<i>M.aksaica</i>						x	xx		
<i>M.articulinos</i>				x					
<i>M. sp</i>			x	x		x			
<i>Spiroplectammina carinata</i>							x	x	
<i>S.carinata oligocenica</i>							x	x	
<i>S. cf. abbreviata</i>							x	x	
<i>Quinqueloculina aknericana</i>							x	x	
<i>Q. triangularis</i>				x			x	x	
<i>Q. boucana</i>							x	x	
<i>Q. consobrina</i>				x	x				
<i>Q. regularis</i>				x					
<i>Q. sp</i>				x					
<i>Bolivina tarchanensis</i>							xx	xx	
<i>B. incrassata</i>								x	
<i>B. Lcyrichi</i>									x
<i>B. advena</i>									x

Continuation of table 10									
		Upper Miocene		Middle Miocene				Miocene lower	Oligocene
Name of microfauna	Age	Pontian	Diatomian layers			Sprialis layers		upper	lower
Foraminifera			Meotian	Sarmatian	Concian	Karaganian	Chokrakian	Tarkhanian	Maycopian
<i>Bulimina inflata</i>									x
<i>B. elongata</i>									x
<i>Uvigerina pygmea</i>							xx	xx	
<i>U. sp</i>					x	x	x		
<i>U. ex gr proboscidea</i>								x	
<i>C.midwayensis</i>									x
<i>C. oligocenicus Sam</i>									x
<i>Streblus ex gr. beccarii</i>							x	x	
<i>Guttalina cf. problema</i>							x	x	
<i>G.ungaricus</i>							x	x	
<i>G.perlucidus</i>								x	
<i>Lenticulina cf hermani</i>								x	
<i>L.inornata</i>							x	x	
<i>Caucasica schishkaniskye</i>							x	x	
<i>Sigmolina tschokrakensis</i>							xx	xx	
<i>Caudina caudata</i>							x	x	
<i>Cassidulina crassa</i>				x			xx	xx	
<i>Streblus beccarii</i>				x					
<i>Articulina problema</i>				x					
<i>Parasonion granosum</i>		xxx	xx	x					
<i>P. martkobi</i>		xxx	xx	x					
<i>P. sarmaticum</i>			xx	x					
<i>Nonion ex gr. punctatus</i>			x						
<i>N. subgranosus</i>			x						
<i>N.vulgaris</i>			x						
<i>N. soldanii</i>			x					x	
<i>N.pricaspicus</i>								x	
<i>N.miocenicus</i>								x	
<i>N. micrus</i>									x
<i>N.asterius</i>					x	x			
<i>Nodosaria hispida</i>									x
<i>N.schlchti</i>									x
<i>N.adolohina</i>									x
<i>N. ambigua</i>									x
<i>Elphidium macellum</i>		xx	xx						
<i>E.umbonatus</i>									x
<i>E. crispum</i>			xx						
<i>E. djalairica</i>			xx						
<i>E. aculeatum</i>			xx						
<i>E.regina</i>			xx						
<i>Ammonia beccarii</i>		xx		x	xx				
<i>Discorbis tschokrakensis</i>						xxx			
<i>Spirorutilus mariae</i>				x		x		x	
<i>Cornuspira striata</i>			x						
<i>Sprialis tschokrakensis</i>		x				xxx			
<i>S. andrussovi</i>		x				xxx			
Legend			rare (1-5)		seldom (5-10)		usulally (10-20)		abundand (<100)

Table 11

Distribution of Ostracod Fauna in Miocene Sediments of the Azerbaijani Sector of the Caspian Sea

Name of species of foraminifera, ostracods and other microfossils	Pleistocene	Eopleistocene	Pliocene upper	Miocene		
				upper		lower
				Sarmatian	Chokrakian	
ostracods:						
<i>L. kopetdagica</i>				x		
<i>Leptocythere stabilis</i>				x	x	
<i>L. mironovi</i>				x		
<i>L.symbula</i>				x		
<i>Cythereis sarmatica</i>				x		
<i>Trahyleberis kolesnikovi</i>				x		
<i>Tr.dramas</i>					x	
<i>Tr. elegantissima</i>					x	
<i>Tr. tschokrakensis</i>					x	
<i>Tr. spinulosa</i>					x	
<i>Euxinocythere bosqueti</i>					x	
<i>Cyprideis littoralis</i>					x	
<i>Cythereis gigas</i>					x	
<i>C. grasilis</i>					x	
<i>Xestoleberis lutrae</i>				x	x	
<i>Limnocythere tschokrakensis</i>					x	
<i>Loxoconcha carinata</i>					x	
<i>L.carinata alata</i>					x	
<i>L. aff. bairdyi</i>					x	
<i>L. impressa</i>				x		
<i>Cytheridea mülleri</i>					x	
Foraminifera:					xx	
<i>Spiroplectammina carinata</i>					xx	
<i>S.carinata oligocenica</i>					xx	
<i>S. cf. abbreviata</i>					xx	
<i>Quinqueloculina aknericana</i>					xx	
<i>Q. boucana</i>					xx	
<i>Bolivina tarchanensis</i>					xx	
<i>Uvigerina pygmaea</i>					xx	
<i>Cibicides lobatulus</i>					xx	
<i>Streblus ex gr. beccarii</i>					xx	
<i>Guttalina cf. problema</i>					xx	
<i>L.inornatus</i>					xx	
<i>Caucasica schishkaniskye</i>					xx	
<i>Caudina caudata</i>					xx	
<i>Cassidulina crassa</i>			x		xx	
<i>Streblus beccarii</i>			x			
<i>Quinqueloculina consobrina</i>				xx		
<i>Articulina problema</i>				xx		
<i>Parasononion granosum</i>				xx		
<i>P. martkobi</i>				xx		
<i>Ammonia beccarii</i>				xx	xx	
<i>Nonion ex gr. punctatus</i>				xx		
<i>Elphidium macellum</i>				xx		
<i>E. crispum</i>				xx		
<i>Ovulites sarmaticus</i>				xx		
bryozoans					xx	
Pelecypoda, gastropoda				xx	xx	

Continuation of table 11						
Name of species of foraminifera, ostracods and other microfossils	Pleistocene	Eopleistocene	Pliocene upper	Miocene		
	Bakuvian	Apscheronian	Akchagylian	upper		lower
				Sarmatian	Chokrakian	Maycopian
bones scales fish teeth				xx	xx	xx
<i>Otholits</i>				xx	xx	
Legend		rare (1-5)		seldom (5-10)		

Table 12 Kazakh sector of the Caspian Sea. Distribution of microfauna in the Skalistaya structure well No 539											
Name of structure	Skalistaya										
Age	Sarmatian						Conkian				
Well number	539										
Number of samples	1	2	3	4	5	6	7	8	9	10	11
Depth intervals	12-15	15-17	17-20	20-25	25-32	35-40	40-50	50-60	60-70	70-80	90-100
Ostracoda:											
<i>Leptocythere mironovi</i>	x			x		x					
<i>L.marginata</i>		x	x		x						
<i>L. symbula</i>	x			x							
<i>L. suzini</i>		x	x		x	x					
<i>L. karaganinca</i>						x					
<i>L.saluta</i>	x	x									
<i>Cyprideis littoralis</i>		x		x		x					
<i>C. punctullata</i>			x		x	x					
<i>Loxoconcha meotica</i>	x										
<i>L. impressa</i>		x		x		x					
<i>L. aff truncata</i>			x		x	x					
<i>Xestoleberis lutrae</i>							x		x		x
<i>X. lunaris</i>							x			x	
<i>Trachyleberis kolesnikovii</i>			x			x					
<i>Cythereis grasilis</i>							x	x	x		x
<i>C. dromas</i>									x	x	
<i>C. sarmatica</i>		x	x		x						
Formainifera: <i>Elphidium macellum</i>		xx									
<i>Spirorutilus mariae</i>											x
<i>Nonion marktobi</i>		xx	xx	xx	xx		xx				
<i>N.vulgaris</i>			xx								
<i>N.pricaspicus</i>	x		x	x	xx		xx		x		xx
<i>N.miocenicus</i>	x		x		x		xx				xx
<i>N. granosus</i>	x		x		x		xx			x	
<i>N.lucidus</i>				xx	xx						
<i>N. pricaspicus</i>	xx	xx		xx	xx						
<i>Uvegerina sp</i>							x		x		
<i>Ammonia beccarii</i>								xx		x	xx
<i>Spirorutilus mariae</i>			x		x						
<i>S. sp</i>			x		x						
<i>Porosonion sarmaticum</i>		x	x		x						
<i>Elphidium crispum</i>	x	xx	xx	x	x						
<i>E. macellum</i>	x			x	x	x			x		x
<i>Cornuspira striata</i>	x			x	x						
<i>Ovulites sarmatica</i>	x			x			xx	xx			
fish scale and bone						xx	xx			xx	xx
other microfauna: <i>Otholitus</i>	x		x			x			x		x
Legend		rare (1-5)			seldom (5-10)						

Table 13

**Kazakh sector of the Caspian Sea. Distribution of microfauna
in the Skalistaya structure well No 561**

Name of structure	Skalistaya				
Age	Meotian				
Well number	561				
Number of samples	2	3	4	5	6
Depth intervals	2-15	15-30	30-45	45-60	60-75
<i>Xestoleberis meotica</i>	x	x			x
<i>X. ovata</i>	x	x			
<i>Leptocythere meotica</i>	x	x			
<i>L. striatocostata</i>	x	x			x
<i>Loxoconcha eichwaldi</i>	x	x			x
<i>Cythereis grasilis</i>	x	x	x	x	x
<i>Tyrrhenocythere azerbaijanica</i>	x			x	
<i>Typhlocypris centropunctata</i>	x				
<i>Miliolina seminulum</i>	x				
<i>Ammonia beccarii</i>	x			x	x
oolits	x	x	xx	xx	xx
<i>Mactra</i>		x			
Legend		rare (1-5)		seldom (5-10)	

Table 14

**Kazakh sector of the Caspian Sea. Distribution of microfauna
in the Skalistaya structure well No 5**

Name of structure	Skalistaya more								
Age	Maycopian								
Well number	5								
Number of samples	1	2	3	4	5	6	7	8	9
Depth intervals	180-190	221-231	288-298	403-413	449-460	478-488	515-525	530-540	595-605
Fish bones	x	x	x	xx	xx	x	x	xx	xx
Fish scales	x	x	x	xx	x	x	x	xx	xx
Legen		rare (1-5)				seldom (5-10)			

4.2. Paleoecological interpretation

Microfaunal assemblages indicate significant environmental changes in the Caspian basin during the Miocene. During the early Miocene, connections between the Eastern and Western Paratethys allowed marine faunal exchange. Later tectonic activity led to periodic basin isolation and salinity fluctuations. These conditions resulted in:

- evolution of endemic species
- replacement of stenohaline fauna by euryhaline assemblages
- reduced diversity in periods of basin restriction

Tarkhanian and Chokrakian assemblages include Mediterranean-type species, suggesting temporary marine connections with the Mediterranean realm. Later stages (Karaganian–Konkian) show evidence of basin desalination and faunal impoverishment, while Sarmatian assemblages indicate relatively stable environmental conditions.

5. Discussion

The microfaunal data obtained from offshore wells confirm the stratigraphic framework previously proposed for Miocene deposits in the Caspian region. In particular, the results support earlier studies conducted on onshore Azerbaijan and several offshore structures in the Kazakh sector [21]. Several common species of ostracods and foraminifera identified in Miocene deposits across all sectors of the Caspian Sea are illustrated in the SEM photographs presented in figures 8, 9.

The distribution of ostracods and foraminifera provides valuable biostratigraphic markers that allow:

- identification of Miocene horizons
- correlation between offshore structures
- reconstruction of paleoenvironmental conditions

Given the importance of Miocene reservoirs within the Caspian petroleum system, such micropaleontological analyses are essential for refining stratigraphic models used in hydrocarbon exploration [4, 5, 13].



Fig. 8. SEM images of selected Miocene foraminifera from wells in the South Caspian Basin

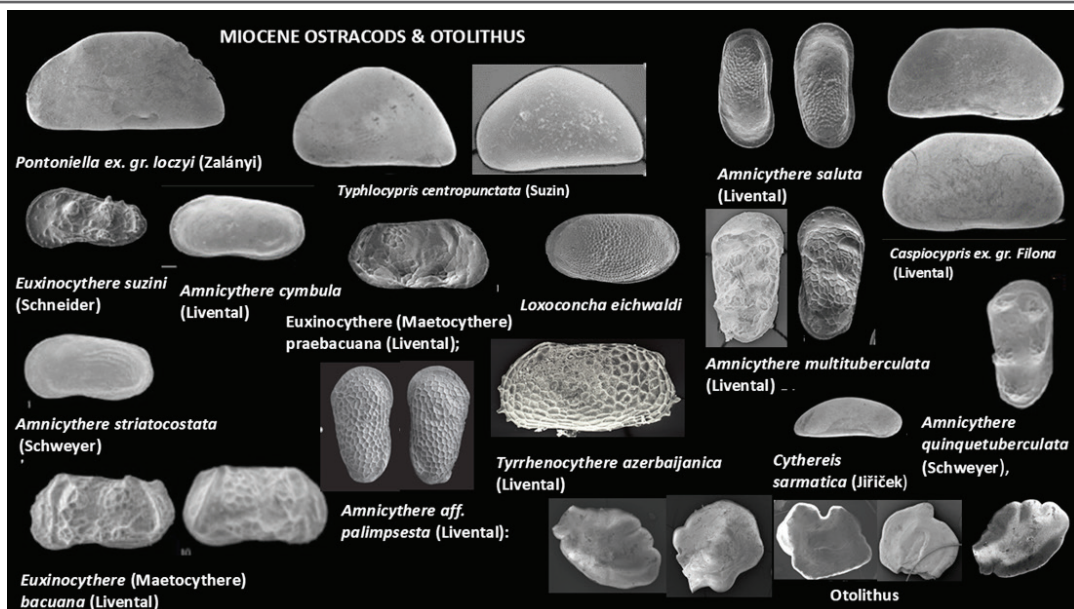


Fig. 9. SEM images of selected Miocene ostracods from wells in the South Caspian Basin

Conclusions

- A detailed understanding of the stratigraphic framework of a region is one of the most important factors for determining effective strategies for hydrocarbon exploration and the discovery of oil and gas fields. To achieve this objective, paleontological analyses were conducted on core materials collected from offshore wells located in the Kazakh, Turkmen, and Azerbaijani sectors of the Caspian Sea.
- Miocene deposits of the South Caspian Basin contain abundant microfauna assemblages dominated by foraminifera and ostracods. A total of 95 species of foraminifera and 40 species of ostracods were identified from 818 samples collected in 134 wells. Ostracods show strong stratigraphic significance and allow identification of several Miocene horizons. Microfauna assemblages reflect significant paleoenvironmental fluctuations related to tectonic activity and changing connections with the Mediterranean and Paratethys basins. The thickness and burial depth of Miocene deposits increase southward from the Middle Caspian toward the South Caspian Basin. However, the composition of ostracod and foraminiferal assemblages remains nearly unchanged.
- The results confirm previously proposed stratigraphic interpretations and provide new data for offshore areas of the Caspian Sea. Micropaleontological analysis remains an essential tool for stratigraphic correlation and hydrocarbon exploration in the Caspian region.

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